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**Storage and transportation systems for gaseous
hydrogen - Part 2: Test methods for evaluating metallic
material compatibility in hydrogen atmosphere**

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Table of Contents

Foreword.....	3
1 Scope.....	4
2 Normative references.....	4
3 Terms and definitions	5
4 Symbols	5
5 Test equipment.....	5
6 Test conditions	7
7 Test methods.....	8
Annex A (informative) Basic structure of main body of test equipment	14

Storage and transportation systems for gaseous hydrogen - Part 2: Test methods for evaluating metallic material compatibility in hydrogen atmosphere

1 Scope

This Standard specifies the test equipment, test conditions and test methods for evaluating metallic material compatibility in hydrogen atmosphere.

This Standard is applicable to the determination of tensile properties, fatigue properties and fracture mechanical properties of metal materials in a gaseous hydrogen atmosphere.

2 Normative references

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

GB/T 228.1, *Metallic materials - Tensile testing - Part 1: Method of test at room temperature*

GB/T 3075, *Metallic materials - Fatigue testing - Axial-force-controlled method*

GB/T 3634.2, *Hydrogen - Part 2: Pure hydrogen, high pure hydrogen and ultrapure hydrogen*

GB/T 6398, *STANDARD test method for fatigue crack growth rates of metallic materials*

GB/T 10623, *Metallic material - Mechanical testing - Vocabulary*

GB/T 15248, *The test method for axial loading constant-amplitude low-cycle fatigue of metallic materials*

GB/T 21143, *Metallic materials - Unified method of test for determination of quasistatic fracture toughness*

GB/T 26077, *Metallic materials - Fatigue testing - Axial-strain-controlled*

5.1.1 See Annex A for the main body of the test equipment for evaluating metallic material compatibility in high pressure hydrogen atmosphere. It is mainly composed of test chamber, support equipment, measuring equipment, loading rod, etc.

5.1.2 Test equipment shall meet the relevant safety requirements of GB/T 29729 and GB/T 34542.1.

5.1.3 The materials of the test equipment shall meet the requirements of the corresponding national standards or industry standards. Materials in direct contact with hydrogen shall have good compatibility with hydrogen.

5.1.4 The temperature and pressure control system of the test equipment shall be able to meet the relevant test requirements.

5.1.5 The gas discharge system of the test equipment shall be provided with a flow control equipment.

5.1.6 During the deactivation of the test equipment, the test chamber shall be filled with 0.1 MPa high purity nitrogen or inert gas for protection.

5.1.7 When the test equipment is deactivated for more than 15 consecutive days, it shall be subject to leak testing first. The test shall be carried out only after it is qualified.

5.2 Test chamber

5.2.1 The materials, design, manufacturing, use management, periodic inspection, etc. of test chamber shall refer to the relevant provisions of TSG 21.

5.2.2 The design of the test chamber shall take into account the effects of fatigue loading and hydrogen on material properties.

5.2.3 The number of pressure cycles in the test chamber design must not be lower than the number of pressure cycles within the expected service life.

5.2.4 It is advisable to use an appropriate equipment to balance the axial force of the gas pressure on the loading rod.

5.3 Measuring equipment

5.3.1 Internal measuring equipment

5.3.1.1 The internal measuring equipment shall be able to withstand the pressure in the test chamber and have the precision and resolution required for the test.

5.3.1.2 The electronic components of the internal measuring equipment shall

7.2.2.1 The test shall be loaded at a constant displacement rate.

7.2.2.2 The strain rate of the gauge section of a smooth round bar sample shall not exceed $2 \times 10^{-5} \text{ s}^{-1}$. For a notched round bar sample, the strain rate of the sample segment with a notch centered at 25.4 mm shall not exceed $2 \times 10^{-6} \text{ s}^{-1}$.

7.2.3 Test report

The test report shall at least contain the following information:

a) Test conditions:

- 1) material designation, specification, chemical composition, heat treatment state, welding process parameters (if necessary);
- 2) sample sampling position, sampling orientation, structural size, surface state;
- 3) gas purity, test temperature, test pressure;
- 4) temperature-time curve, pressure-time curve of test chamber.

b) Test parameters:

strain rate.

c) Test result:

- 1) stress-strain curve;
- 2) yield strength, tensile strength, elongation after fracture and reduction of area.

7.3 Fatigue life test

7.3.1 Test equipment and samples

7.3.1.1 Fatigue life test shall use force control or strain control. In addition to the requirements of Clause 5, the test equipment shall also meet the relevant requirements of GB/T 3075 when force control is adopted. When using strain control, it shall also meet the relevant requirements of GB/T 15248 or GB/T 26077.

7.3.1.2 Fatigue life test shall use smooth round bar sample or notched round bar sample. When using force control, the smooth round bar sample shall meet the relevant requirements of GB/T 3075. When using strain control, the smooth round bar sample shall meet the relevant requirements of GB/T 15248 or GB/T 26077. Samples with notched round bars shall be of standard samples as shown in Figure 1, or samples with a notched stress concentration factor

7.4.1 Test equipment and samples

7.4.1.1 In addition to the provisions of Clause 5, the test equipment shall also meet the relevant requirements of GB/T 21143.

7.4.1.2 The sample shall meet the relevant requirements of GB/T 21143.

7.4.2 Test procedures

7.4.2.1 The test procedures shall meet the relevant requirements of GB/T 21143.

7.4.2.2 The test shall use displacement control. Use the gap opening displacement or the beam displacement as the control variable.

7.4.2.3 The stress intensity factor rate in the linear elastic region of the sample shall be between $0.1 \text{ MPa} \cdot \text{m}^{1/2}/\text{min} \sim 1 \text{ MPa} \cdot \text{m}^{1/2}/\text{min}$.

7.4.3 Test report

The test report shall at least contain the following information:

a) Test conditions:

- 1) material designation, specification, chemical composition, heat treatment state, welding process parameters (if necessary);
- 2) sample sampling position, sampling orientation, structural size, surface state;
- 3) gas purity, test temperature, test pressure;
- 4) temperature-time curve, pressure-time curve of test chamber.

b) Test parameters:

- 1) displacement rate;
- 2) displacement control method.

c) Test result:

fracture toughness value.

7.5 Fatigue crack growth rate test

7.5.1 Test equipment and samples

7.5.1.1 In addition to the provisions of Clause 5, the test equipment shall also meet the relevant requirements of GB/T 6398.

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