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Metallic materials - In-situ testing method - Part 1: Tensile test

金属材料 原位试验方法 第1部分：拉伸试验

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1 Scope

This document specifies the principles, specimens, test equipment, test procedures, test result processing and test report of the in-situ tensile test method for metallic materials.

This document is suitable for obtaining the tensile mechanical properties, microstructural evolution process or quantitative microscopic characterization results of metallic materials in in-situ tensile test.

2 Normative References

GB/T 228.1

GB/T 228.2

GB/T 228.3

GB/T 10623

GB/T 12160

GB/T 16825.1

GB/T 34104

JJF 1637

JJG 141

JJG 762

3 Terms and Definitions

The terms and definitions defined in GB/T 10623 and the following are applicable to this document.

3.1 In-situ tensile test

A test method that combines microstructural characterization techniques while simultaneously applying tensile load to obtain data on the microstructural evolution and failure process of a material in real time.

3.2 Hold time

The time during which the specimen is held under a constant loading state.

NOTE. during this period, the specimen undergoes specific microstructural evolution, stress relaxation, creep, dislocation movement, etc., without further loading or unloading.

3.3 Interrupted test

In an in-situ tensile test, the specimen is held at a specific displacement (strain) or load (stress) level, and during the hold time, the microstructure of the specimen is observed, characterized, or otherwise analyzed.

3.4 Strain field

The spatial distribution of strain at various points in a material under external force due to deformation.

NOTE. it describes the degree of deformation of a material in space and is usually expressed by the strain tensor, including normal strain (tension or compression) and shear strain (shear deformation), etc. The distribution of the strain field is closely related to external loading conditions, the geometrical shape of the material, and its microstructure, and is one of the modes to study the deformation behavior and mechanical response of a material.

3.5 Deformation mechanism

The basic process and mechanism by which a material undergoes plastic deformation under external force.

NOTE. common deformation mechanisms include slip, twinning, and phase transformation. These deformation mechanisms may simultaneously or alternately occur under different materials and loading conditions, collectively determining the overall deformation behavior of the material.

3.6 Failure mechanism

In tensile test, the specific process and cause of material damage accumulation and fracture due to external force.

NOTE. these failure mechanisms are usually closely related to the material's microstructure, the application of external force, temperature, and other factors, and are an important constituent part of the material failure process in tensile test. Common failure mechanisms include plastic failure, cleavage cracking, grain boundary cracking, and void evolution, etc.

4 Principle

Tensile tests are conducted at room temperature or in complex environments (for example, high temperature) using a dedicated in-situ mechanical loading device and its matching strain acquisition device and environmental accessories, along with various microscopic characterization devices. This allows for the acquisition of the material's tensile mechanical properties, microstructural evolution process, or quantitative microscopic characterization results.

5.1 Geometric Shape of Specimens

5.1.1 The geometric shape of specimens depends on the shape and size of the metal product under test and shall be compatible with the dedicated in-situ mechanical loading device and its matching strain acquisition device, environmental accessories, and microscopic characterization devices.

5.1.2 While meeting the requirements for microscopic observation, the shape and size of the specimens should preferably meet the requirements of GB/T 228.1, GB/T 228.2 and

GB/T 228.3 Recommended tensile specimen forms include plate specimens, rod specimens, tubular specimens, and longitudinally arc-shaped specimens, etc. Specific shapes and sizes are given in Appendix A.

5.1.3 The size selection of the specimens shall meet the measuring range requirements of the in-situ mechanical loading device used (the maximum test force is recommended to be around 2/3 of the measuring range), and the center plane of the specimens shall be coplanar with the loading plane and the center plane of the force sensor.

5.2 Specimen Preparation

Rough specimens shall be cut, and specimens shall be prepared in accordance with the relevant product standard requirements of the material. The surface condition of the specimens shall meet the general requirements of the microscopic characterization instrument used.

5.3 Specimen Storage and Transportation

Specimens shall be protected from scratches, oxidation and bending deformation, etc. They should preferably be stored in individual boxes or pipes with sealed heads. Polished specimens shall be stored in vacuum bottles or desiccators containing silica gel.

6.1 General Requirements

Test equipment generally includes a dedicated in-situ mechanical loading device and auxiliary strain acquisition device, high and low temperature environmental loading device, and supporting microscopic characterization device. Typically, the loading device, acquisition device, and environmental loading device are installed inside or deeply integrated with the microscopic characterization device.

6.2.1 In-situ mechanical loading devices typically employ bidirectional symmetrical loading to

fix the specimen's center position relative to the microscopic characterization device, i.e., the observation point position remains unchanged, which facilitates the characterization within a fixed area.

6.2.2 If a single-end actuated mechanical loading device is used, it shall be used in conjunction with a two-dimensional platform that fixes the loading device. Before characterization begins, the position of the loading device or the detector of the microscopic characterization device shall be appropriately moved to ensure that the observation area on the specimen remains essentially unchanged. For special microscopic characterization devices, additional moving mechanisms can be added to the in-situ mechanical loading device as needed, for example, the Eulerian circulation mechanism used in in-situ neutron