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**Metallic materials - Compression test method at elevated
temperature**

金属材料 高温压缩试验方法

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Metallic materials - Compression test method at elevated temperature

1 Scope

This document specifies the principle, specimens, test equipment, test conditions, performance determination, rounding off for numerical values of test results, test result processing and test report of compression test methods at elevated temperature for metallic materials.

This document applies to the determination of parameters such as the specified plastic compressive strength, specified total compressive strength, upper compressive yield strength, lower compressive yield strength, compression elastic modulus and compressive strength of uniaxial compression at temperatures higher than room temperature.

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 7314 Metallic materials - Compression test method at room temperature

GB/T 8170 Rules of rounding off for numerical values & expression and judgement of limiting values

GB/T 10623 Metallic material - Mechanical testing - Vocabulary

GB/T 12160 Metallic materials - Calibration of extensometers systems used in uniaxial testing

GB/T 16825.1 Metallic materials - Calibration and verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Calibration and verification of the force-measuring system

3 Terms and definitions

For the purpose of this document, the terms and definitions defined in GB/T 7314 and GB/T 10623 and the following apply.

3.1

6.1.2 Figures 1 and 2 are specimens without lateral restraint. Specimens with $L = (2.5 \sim 3.5)d$ and $L = (2.5 \sim 3.5)b$ are suitable for the determination of R_{pe} , R_{te} , R_{eHc} , R_{eLc} , and R_{mc} . Specimens with $L = (5 \sim 8)d$ and $L = (5 \sim 8)b$ are suitable for the determination of $R_{pe0.01}$ and E_c . Specimens with $L = (1 \sim 2)d$ and $L = (1 \sim 2)b$ are only suitable for the determination of R_{mc} .

6.1.3 Figures 3 and 4 are plate-shaped specimens, which shall be clamped in a restraint device for testing.

6.1.4 The distance between the two ends of the original gauge length of the specimen and the end face of the specimen shall not be less than half of the specimen diameter (or width).

6.1.5 The length of plate-shaped specimens is calculated according to formula (1):

$$L = H + h \quad \dots\dots\dots (1)$$

6.1.6 The length of the unrestrained part of plate-shaped specimens shall be calculated based on the relevant mechanical properties of the material being tested and the height of the restraint device. The indenter shall not contact the restraint device during compression.

6.2 Specimen preparation

6.2.1 The number, location, and orientation of the sample blank cut shall comply with the relevant product standards or the agreement between the relevant parties.

6.2.2 When cutting the sample blank and machining the specimen, the material properties shall be prevented from being changed due to cold working or heat.

6.2.3 When the thickness of the plate-shaped specimen is the product thickness, the original surface shall be retained and there shall be no scratches or other damage on the surface; when the thickness of the specimen is the machining thickness, the surface roughness shall not be inferior to the roughness of the original surface. The allowable deviation of the thickness (or diameter) within the gauge length is 1 % or 0.05 mm, whichever is smaller.

6.2.4 Cylindrical specimens are machined according to Figure 1; specimens with rectangular cross-section are machined according to Table 2. The edges shall be free of burrs.

6.2.5 Specimens shall be straight. Specimens cut from the plate roll or strip roll is allowed to have a slight bend that does not affect the performance determination.

7 Test equipment

7.1 Testing machine

7.1.1 The accuracy of the testing machine shall be level 1 or better and shall meet the requirements of GB/T 16825.1.

7.1.2 The working surfaces of the upper and lower pressing plates of the testing machine shall be parallel, with a parallelism of not less than $0.0002 : 1 \text{ mm/mm}$ (within 100 mm of the installation area). The material of the pressing plates shall have sufficient hardness and oxidation resistance at the test temperature to prevent plastic indentation or eccentricity under the maximum load. The hardness of the pressing plates should not be less than 55 HRC.

7.1.3 The two ends of the specimen with higher hardness shall be backed by suitable hard materials. After the test, the plate surface shall not have permanent deformation. The parallelism of the upper and lower surfaces of the backing plate shall not be less than $0.0002 : 1 \text{ mm/mm}$, and the surface roughness R_a shall not be greater than $0.8 \mu\text{m}$.

7.2 Additional devices

7.2.1 Additional devices include: force guide device, leveling pad, protective cover, and restraint device.

7.2.2 For testing machines that do not meet the requirements for the parallelism of pressing plates, force guide devices shall be added; when the influence of eccentric compression of the testing machine is more obvious, leveling pads can be used; when testing brittle materials, a protective cover or iron gauze that can withstand the test temperature and is easy to observe shall be used to cover the specimen to prevent specimen fragments from flying out or damaging the instrument.

7.2.3 For compression tests of plate-shaped specimens, restraint devices shall be used.

NOTE: Restraint devices refer to devices used to support the plate-shaped specimen laterally to prevent buckling during compression of the specimen and do not affect axial deformation.

7.2.4 Additional devices shall comply with the requirements of GB/T 7314 and shall not deform at high temperatures.

7.3 Extensometer

Extensometers shall comply with the requirements of GB/T 12160. When determining the compression elastic modulus, an extensometer of not less than grade 0.5 shall be used. When testing the specified plastic compressive strength, total compressive strength, and compressive yield strength, an extensometer of not less than grade 1 shall be used. When determining the compression elastic modulus and the specified plastic compressive strength with a specified plastic compressive strain less than 0.05 %, it is recommended to use an average extensometer.

7.4 Heating device

7.4.1 The heating device shall be able to heat the specimen to the specified temperature T . This document recommends the use of a radiation heating furnace.

7.4.2 The constant temperature zone of the heating furnace shall not be less than twice the gauge length of the specimen, and the furnace space shall be large enough not to hinder the use of various test devices.

7.4.3 The allowable deviation and temperature gradient of the measured temperature T_i and the specified temperature T are shown in Table 3.

NOTE: T_i refers to the temperature measured on the parallel length surface of the specimen. The temperature has been corrected for systematic errors, but the uncertainty of the temperature measuring device has not been considered.

7.5 Temperature measurement system

7.5.1 The temperature measurement system shall be qualified. If it is known from experience that the relative position of the heating device and the specimen can ensure that the change of the specimen temperature complies with the provisions of Table 3, the number of thermocouples can be reduced, but at least one temperature measuring thermocouple shall be ensured to maintain good thermal contact with the specimen

When installing a specimen, graphite lubricant shall be applied to both ends of the specimen, and the specimen shall be parallel and aligned with the upper and lower fixtures. When a restraint device is used for a plate-shaped specimen, graphite lubricant shall also be applied to both ends of the specimen and the fixtures.

8.3 Heating and temperature measurement

8.3.1 Unless otherwise specified in the product standard, the specimen shall be heated to the specified temperature within 1 h, and the soaking time shall not be less than 20 min.

8.3.2 During the test, the allowable deviation and temperature gradient of the test temperature shall comply with the provisions of Table 3.

8.4 Loading rate

8.4.1 When strain control is used during the test, the strain rate is set to 0.005 min^{-1} [$(0.005 \pm 0.002) \text{ min}^{-1}$]; when load control or beam displacement control is used, it should set a speed equivalent to a strain rate of 0.005 min^{-1} for control. If the material is sensitive to strain rate, a strain rate of 0.003 min^{-1} can be used.

8.4.2 When beam displacement rate control is used, it shall maintain a constant beam displacement rate to achieve the average strain rate required during the test.

8.4.3 A constant beam displacement rate during the test does not necessarily guarantee a constant strain rate during the test. Regardless of which method is used, a constant rate shall be used, and no sudden changes in strain rate are allowed.

9 Performance determination

9.1 Selection of clamping force for plate-shaped specimens

The clamping force is selected according to the specified plastic compressive strength $R_{pc0.2}$ (or lower compressive yield strength) of the material and the thickness of the plate. Generally, the friction force F_f is not greater than 2 % of the estimated value of $F_{pc0.2}$; for extremely thin specimens, the friction force is allowed to reach 5 % of $F_{pc0.2}$. Under the condition of ensuring the normal progress of the test, the clamping force should be as small as possible.

NOTE: It is generally considered that specimens with a thickness of less than 0.3 mm are extremely thin specimens.

9.2 Determination of actual compressive force (F) of plate-shaped specimens

9.2.1 The force-deformation curve is automatically plotted during the test. Generally, the initial part is not a linear relationship due to the influence of friction force. When the force is large enough, the friction force reaches a constant value, and then the

a) Test without lateral restraint

b) Test with lateral restraint

Figure 8 -- Determination of F_{tc} by force-deformation graphical method**9.5 Determination of upper compressive yield strength (R_{eHc}) and lower compressive yield strength (R_{eLc})**

On the force-deformation curve, the maximum actual compressive force (F_{eHc}) before the first drop in force and the minimum actual compressive force (F_{eLc}) in the yield stage when the initial transient effect is ignored are determined, and then divided by the original cross-sectional area S_0 of the specimen to obtain the upper compressive yield strength and the lower compressive yield strength.

9.6 Determination of compressive strength (R_{mc})

The specimen is compressed to failure, and the maximum compressive force F_{mc} is determined from the force-deformation curve. The compressive strength is calculated according to formula (5):

$$R_{mc} = F_{mc} / S_0 \quad \dots\dots\dots (5)$$

9.7 Determination of compression elastic modulus E_c

The compression elastic modulus is determined using the force-deformation graphical method, as shown in Figure 8. On the force-deformation curve, take points J and K of the elastic straight line segment (the distance between the points is as long as possible), read the corresponding force values F_J , F_K and deformations ΔL_J , ΔL_K , and calculate according to formula (6).

$$E_c = \frac{(F_K - F_J) \cdot L_0}{(\Delta L_K - \Delta L_J) \cdot S_0} \quad \dots\dots\dots (6)$$

where:

F_K - the force at point K on the force-deformation curve, in Newton (N);

F_J - the force at point J on the force-deformation curve, in Newton (N);

L_0 - the original gauge length of the specimen, in millimeters (mm);

ΔL_K - the deformation at point K on the force-deformation curve, in millimeters (mm);

ΔL_J - the deformation at point J on the force-deformation curve, in millimeters (mm);

S_0 - the original cross-sectional area of the specimen, in square millimeters (mm²).

10 Rounding off for numerical values of test results

The test results shall be rounded off in accordance with the requirements of relevant product standards. If there are no specific regulations, they shall be rounded off in accordance with the following requirements:

- a) the strength properties shall be rounded off to 1 MPa;
- b) the determination results of compression elastic modulus shall retain 3 significant digits, and the rounding off method shall be carried out in accordance with GB/T 8170.

11 Processing of test results

11.1 If any of the following situations occurs, the test results are invalid and the same number of tests shall be repeated:

- a) the specimen buckles before it meets the test purpose;
- b) the specimen end is partially damaged, or the specimen breaks at the lug part or outside the gauge length before it meets the test purpose;
- c) the test equipment fails during the test, affecting the test results.

11.2 If metallurgical defects (such as delamination, blisters, slag inclusions, shrinkage cavities, etc.) appear on the specimen, they shall be noted in the test records and reports.

12 Test report

The test report shall include the following:

- a) serial number of this document;
- b) specimen identification;
- c) material name and designation;
- d) sampling direction and position of specimens;
- e) specimen shape and dimensions;
- f) specimen device and lubricant;
- g) model and specifications of testing machine;
- h) test conditions (test speed, control method);

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