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The test method for elastic modulus of carbon materials

炭素材料弹性模量测定方法

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1 Scope

The document describes methods for determining the elastic modulus of carbon materials and the test report.

It applies to the determination of the elastic modulus of carbon materials at room temperature.

2 Normative references

The content of the following documents constitutes indispensable provisions of this document through normative reference in the text. For dated references, only the version corresponding to that date applies; for undated references, the latest version, including all amendments, applies.

GB/T 1427 Sampling methods for carbon materials; GB/T 8170 Rules of rounding off for numerical values and expression and judgement of limiting values; GB/T 8718 Terminology of carbon materials.

3 Terms and definitions

The terms and definitions given in GB/T 8718 apply to this document.

4.1 Method one: resonance method

Principle: a transmitting transducer converts an electrical signal into a vibration signal which drives the test piece; a receiving transducer picks the vibration up and converts it back into

an electrical signal; the pattern formed by this signal on an oscilloscope is analysed to obtain the natural frequency of the test piece, from which the elastic modulus is calculated.

Instruments and equipment: an exciter converting electrical energy into mechanical energy, used to excite resonance in the test piece; a receiver converting mechanical energy into electrical energy, used to pick up the resonance signal of the test piece; a driving circuit supplying an audio frequency sinusoidal electrical signal; a detecting circuit amplifying and displaying the electrical signal from the receiver; a test piece support; a vernier caliper with a measuring range of 0 mm to 200 mm and a scale interval of 0.02 mm; a forced air drying oven working from room temperature to 200 °C; and a balance with a scale interval of 0.01 g.

Test pieces, graphite electrodes: sampling and machining follow GB/T 1427.

Test pieces, isostatic graphite: the sampling batch follows GB/T 1427; the sampling tool is a hollow drill of 30 mm inside diameter and 200 mm length, or another tool able to meet the test piece requirements; the sampling position and method consist in drilling one cylinder 180 mm long perpendicularly at the centre of the end face of each sample; the cylinder is machined into a test piece of 20 mm plus or minus 0.1 mm diameter by 160 mm plus or minus 0.1 mm length, or of 10 mm plus or minus 0.1 mm diameter by 120 mm plus or minus 0.1 mm length; the appearance of the test piece shows complete edges and corners without visible cracks or flaws; and the two end faces are perpendicular to the longitudinal axis.

Test pieces, other carbon materials: sampling follows the corresponding product standard or the agreement between supplier and purchaser, and the test piece is machined to 30 mm plus or minus 0.1 mm diameter by 180 mm plus or minus 0.1 mm length, or 20 mm plus or minus 0.1 mm diameter by 160 mm plus or minus 0.1 mm length, or 10 mm plus or minus 0.1 mm diameter by 120 mm plus or minus 0.1 mm length.

Test procedure: the test piece is dried for 2 h in an oven at 110 °C plus or minus 5 °C and cooled to room temperature in a desiccator. Its diameter d, length l and mass m are measured. The diameter is measured along the axis at three places, in the middle and at the two ends, twice at each place with the two diameters perpendicular to each other, and the 6 readings are averaged. The length is measured once every 120° around the circumference, 3 measurements in all, and averaged. The ratio of diameter to length is calculated and the correction factor Cr is read from Table 1 against that ratio.

All instruments are switched on and warmed up for 30 min, and the sensitivity and stability of the equipment are checked with a stainless steel rod of known resonance frequency; the test arrangement is shown in Figure 1.

The test piece is hung, or laid, by its two ends on the support and kept horizontal; the output frequency of the audio signal is varied in steps of 1 Hz to force the test piece into resonance at its fundamental frequency, and the resonance frequency is recorded. The test

piece is then rotated 90° about its axis and the operation is repeated; the mean of the two measurements is taken. The two measured values are not to differ by more than 10 %, otherwise the measurement result is void and the test is repeated.

Calculation: the elastic modulus E of the test piece is calculated from equation (1). The equation as printed could not be reconstructed from the digitised text and is therefore not reproduced; its symbols are E, elastic modulus, in gigapascals; Cr, correction factor of the test piece for the resonance method; m, mass of the test piece, in grams; f, frequency, in hertz; d, diameter of the test piece, in millimetres. The result is calculated to one decimal place, rounding being carried out in accordance with GB/T 8170. The calculated result applies to a single sample only.

Table 1 tabulates the correction factor Cr against the diameter to length ratio d/l, in three pairs of columns each giving d/l and the corresponding Cr. In the digitised text the figures of the two columns run together and the values of Cr cannot be matched to the values of d/l, so they are not reproduced here.

4.2 Method two: sonic velocity method

Principle: a signal generator produces an ultrasonic signal, the travel time of the signal through the test piece is measured, the velocity of propagation in the test piece is obtained and the elastic modulus is calculated from it.

Instruments and equipment: a driving circuit incorporating an ultrasonic pulse generator able to produce pulses from 20 kHz to 2.5 MHz; an input transducer; an output transducer; and an automatic display of ultrasonic travel time or a dual trace oscilloscope.

Test pieces: the test piece is a finished machined graphite electrode with a uniform cross-section and free from added liquid; the deviation from perpendicularity of the end face of the test piece with respect to the axis of the graphite electrode is not greater than 0.125 mm. The weighing of the mass and the measurement of the dimensions are accurate to within plus or minus 0.5 %.

Test procedure: the apparatus is connected as shown in Figure 2 and warmed up for 15 min. Glycerol or another suitable couplant is applied to the input and output transducers. The two transducers are butted together to measure the inherent travel time of the instrument and the transducers. The input and output transducers are then pressed against the centre of the bottom of the socket at each end of the graphite electrode and the travel time of the ultrasound is measured.

The key to Figure 2 identifies: 1, digital time display; 2, ultrasonic pulse generator; 3, input transducer; 4, output transducer; 5, dual trace oscilloscope.

Calculation: the sonic velocity v is calculated from equation (2) and the elastic modulus E from equation (3). Both equations are damaged in the digitised text and are therefore not

reproduced; their symbols are v, sonic velocity, in metres per second; l, length of the test piece, in metres; tt, travel time of the ultrasound, in seconds; t0, inherent travel time of the instrument and the transducers, in seconds; C, correction factor of the test piece for the sonic velocity method, whose value for graphite is 0.933; dk, bulk density of the test piece, in grams per cubic centimetre.

4.3 Method three: impulse excitation method

Principle: a single elastic impact from an impulse tool on a test piece of suitable geometry excites its fundamental resonance frequency, which is measured; the elastic modulus is then calculated from that frequency together with the geometry and the mass of the test piece.

Instruments and equipment: a test piece support, laid horizontally on vibration isolating material, whose supporting material in contact with the test piece may be a flat sharp edge or a cylinder of light material, suspension wires being permitted as an alternative; an impact tool whose end in contact with the test piece is a stainless steel sphere fixed to the end of an elastic composite handle of suitable length; an audio transducer covering at least the frequency range 100 Hz to 20 kHz, whose maximum receivable frequency before a power loss of minus 3 dB occurs is at least 10 % above the upper limit of the frequency measuring range; a signal amplifier; a frequency analyser with an accuracy of 0.1 % of full scale; a frequency reader; a vernier caliper with a measuring range of 0 mm to 200 mm and a scale interval of 0.02 mm; a forced air drying oven working from room temperature to 200 °C; and a balance with a scale interval of 0.01 g.

Test pieces: the test piece is machined into a regular rectangular block or a cylinder. For a rectangular block the ratio of length to width and the ratio of length to height are at least 5; for a cylinder the ratio of the length to the diameter of the cross-section is at least 5; and the smallest dimension of the test piece is at least 4 times the size of the largest particle it contains. The test piece is dried for 2 h in an oven at 110 °C plus or minus 5 °C and cooled to room temperature in a desiccator, and its mass is weighed on an electronic balance to the nearest 0.01 g. A rectangular test piece is measured 3 times at different positions in each of the length, width and thickness directions, the greatest deviation between readings in any one direction not exceeding 0.5 %, and the mean is taken for each direction. The diameter of a cylindrical test piece is measured along the axis at three places, in the middle and at the two ends, twice at each place with the two diameters perpendicular to each other, and the 6 readings are averaged; the length is measured once every 120° around the circumference, 3 measurements in all, and averaged; the greatest deviation between readings in any one direction does not exceed 0.5 %.

Test procedure: all electronic equipment is connected and switched on as shown in Figure 3 and adjusted until stable. A rectangular calibration sample of metal is used to verify the response and accuracy of the equipment by the steps below, the calibration sample being