ICS 83.120
CCS Q 23

NATIONAL STANDARD OF THE PEOPLE'S REPUBLIC OF CHINA

GB/T 43938.1-2024

Test method for mechanical properties of thin-walled tube of carbon fiber reinforced composite - Part 1: Tensile testing

碳纤维增强复合材料薄壁管件力学性能试验方法 第1部分:拉伸试验

Issued on: April 25, 2024 **Implemented on: August 1, 2024**

Issued by: State Administration for Market Regulation;
Standardization Administration of the PRC

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1 Scope

The document fixes the specimen, the test conditions, the apparatus, the test procedure, the treatment of data and the test report for the axial tensile test on thin-walled tubes of carbon fibre reinforced composite.

It applies to the determination of the axial tensile strength and the axial tensile modulus of

carbon fibre reinforced composite thin-walled tubes with a wall thickness of not more than 1 mm and a nominal outside diameter of less than 50 mm; thin-walled tubes of other fibre reinforced composites may follow it by reference. The normative references are GB/T 1446-2005 on the general rules for testing fibre reinforced plastics and GB/T 7124 on the tensile shear strength of adhesives. The document defines no terms of its own.

This is the first part of GB/T 43938; the introduction states that the series is planned in two parts, the second covering the compression test.

4 Test specimen

The specimen is not the tube alone. Figure 1 shows it as four items: an inner sleeve, an outer sleeve, the tube test piece and the adhesive layer that joins them.

The tube test piece takes the form of Figure 2 and its dimensions meet Table 1. That table is in millimetres and has two columns, the effective test section length and the clamping section length at the two ends. Its two printed values are, for the effective test section length, not less than 100 with a footnote stating that the effective test section should preferably lie between 100 mm and 200 mm, and, for the clamping section length, 150 +/- 0.5. The parallelism of the two end faces of the tube test piece is not more than 0.05 mm and their perpendicularity to the axis not more than 0.05 mm.

The tube test piece is cut directly from the product or from a witness piece cured with the same batch, so that its material and lay-up match the state of the corresponding product. Its surface is free of visible mechanical damage, and machining is not to produce delamination, score marks or local crushing; after machining the end faces are flat and the surface free of visible mechanical damage.

The inner sleeve takes the form of Figure 3. The diameter of its bonded section fits the inner diameter of the tube test piece with a single side clearance of (0.2 +/- 0.1) mm; its bonded length equals the clamping section length of the tube test piece; its wall thickness is 2 mm to 5 mm; its fitting height is 3 mm to 5 mm; and the outside diameter of its assembly section is 4 mm to 6 mm larger than the outside diameter of the tube test piece. It is preferably made of 2A12 aluminium alloy in the T4 condition and is surface treated before bonding, phosphoric acid anodising being preferred.

The outer sleeve takes the form of Figure 4. Its inner diameter fits the outside diameter of the tube test piece with a single side clearance of (0.2 +/- 0.1) mm; its bonded length equals the clamping section length of the tube test piece; the width of its mating face is 5 mm to 10 mm larger than the outside diameter of the tube test piece; the height of its clamping section is half the total length of the tensile outer sleeve; the outside diameter of its assembly section is 0.2 mm to 0.3 mm larger than that of the inner sleeve; and its outside diameter is 10 mm to 15 mm larger than the outside diameter of the tube test piece. The flatness of the face that contacts the adaptor fixture is not more than 0.05 mm. The

material and the surface treatment are those of the inner sleeve.

In preparing the specimen the inner and outer sleeves are joined to the tube test piece by bonding. Before bonding, the inner diameter of the tube is measured at four equally spaced positions on each end face and averaged, and the outside diameter is measured in two perpendicular directions at three cross sections of the effective test section and averaged; both means are recorded. A room temperature curing adhesive with a room temperature shear strength above 25 MPa is preferred, the shear strength being measured by GB/T 7124, and the bond gap between the tube and the sleeves is (0.2 +/- 0.1) mm.

The bonding area of the tube test piece is roughened without damaging the fibre reinforcement, a layer of adhesive is spread evenly over the bonding areas of tube, inner sleeve and outer sleeve, the parts are assembled and bonded as in Figure 1, the adhesive is cured as its manufacturer or another applicable material standard requires, the specimen is held upright during curing and squeezed-out adhesive is cleaned off as it appears. The perpendicularity of the specimen end face to the axis of the tube test piece is not more than 0.05 mm and the coaxiality of the two tensile sleeves not more than 0.1 mm.

Each group has at least five specimens, and at least five valid specimens are required from one batch.

5 Test conditions

The laboratory environment follows Clause 3 of GB/T 1446-2005. Where it does, the specimen is kept at (23 +/- 2) °C for at least 4 h and tested in the same environment; for an arbitration test the specimen is kept at (23 +/- 2) °C and (50 +/- 10) % relative humidity for at least 40 h.

The loading speed for the tensile strength is 1 mm/min to 5 mm/min, and 2 mm/min for an arbitration test; the loading speed for the tensile modulus is 2 mm/min.

The fixture and the way the specimen is held in it follow Figure 5, and the fixture itself Figure 6. The diameter of its column section is matched to the testing machine and is generally not less than 20 mm; the diameter of the centring pin hole is matched to the testing machine; the wall thickness of the fixture is matched to the testing machine and is generally not less than 10 mm; the width of the inner cavity of the fixture is not less than the outside diameter of the tensile outer sleeve by 2 mm to 5 mm; the width of the mating face of the fixture matches the width of the mating face of the tensile outer sleeve, the fit clearance generally being not more than 1 mm; and the fixture is preferably made of grade 45 quality carbon structural steel.

7 Apparatus and test procedure

The apparatus follows Clause 5 of GB/T 1446-2005.

In preparing for the test the appearance of the specimen is checked, the inner and outer diameters of the tube test piece are taken from the values recorded during specimen preparation, the specimen is numbered, and it is conditioned as the test conditions require.

The fixtures are first mounted between the two heads of the testing machine and the specimen is then mounted in the fixtures as in Figure 5. Instruments for measuring deformation are fitted to the working section of the specimen, an initial load of about 5 % of the failure load is applied, and the specimen and the deformation measuring instruments are checked and adjusted so that the whole system is working normally. On the same specimen the tensile modulus is measured first and the tensile strength afterwards.

For the modulus, loading may be continuous where an automatic recording device is available and is otherwise applied in steps, the applied load preferably not exceeding 50 % of the failure load. Where step loading is used the step is 5 % to 10 % of the failure load, there are not fewer than five steps, the measurement is generally repeated at least three times, two stable deformation increments are taken, and the loads of each step and the corresponding deformation values are recorded. Strain gauges are preferred: one is bonded on each of two diametrically opposite positions at the middle of the effective test section, as shown in Figure 7. Where the tube test piece is too small for strain gauges, the deformation may be measured by other means such as an extensometer.

For the strength, a uniform and continuous load is applied to the specimen until it fails; the failure load and the way the specimen failed are recorded.

A specimen is void where the tube test piece has debonded from the inner or outer sleeve, or where the specimen has failed outside the effective test section. Where fewer than five valid specimens remain in a batch, new specimens are made and tested.

8 Treatment of data and test report

The axial tensile strength, in MPa, is obtained from the failure load in N and from the outside and inner diameters of the tube test piece in mm, which give the cross sectional area of the tube wall.

The axial tensile modulus, in MPa, is obtained from the gauge length of the measuring instrument in mm, the load increment within the elastic range of the material in N, the deformation increment over that gauge length corresponding to the load increment in mm, and the same two tube diameters.

The arithmetic mean, the standard deviation and the coefficient of variation of the test results are calculated in accordance with Clause 6 of GB/T 1446-2005.

The test report carries at least the name of the test item and the number of this document; the source and preparation of the specimens and the type and specification of the material; the specimen number, shape, dimensions, appearance quality and quantity; the test