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Carbon Fiber - Determination of Tensile Properties of Resin-impregnated Yarn

碳纤维 浸胶纱拉伸性能的测定

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Carbon Fiber - Determination of Tensile Properties of Resin-impregnated Yarn

1 Scope

This document specifies the determination methods for the tensile strength, tensile elastic modulus and tensile strain of carbon fiber - resin-impregnated yarn.

This document is applicable to carbon fiber yarn.

2 Normative References

The contents of the following documents constitute indispensable clauses of this document through the normative references in the text. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB/T 1040.1 Plastics - Determination of Tensile Properties - Part 1: General Principles

GB/T 7690.1 Reinforcements - Test Method for Yarns - Part 1: Determination of Linear Density

GB/T 29761 Carbon Fiber - Determination of Sizing Content

GB/T 30019 Carbon Fiber - Determination of Density

GB/T 40724 Terminology for Carbon Fiber and Carbon Fiber Composites

3 Terms and Definitions

The terms and definitions defined in GB/T 1040.1 and GB/T 40724 are applicable to this document.

4 Symbols

The following symbols are applicable to this document.

A_f: cross-sectional area of yarn, expressed in (mm^2).

E_f: tensile elastic modulus, expressed in (GPa).

F_f: maximum tensile load, expressed in (N).

L_0: extensometer gauge length, expressed in (mm).

T_{tf}: linear density of yarn, expressed in (tex).

T_{ti}: linear density of resin-impregnated yarn, expressed in (tex).

σ_f: tensile strength, expressed in (MPa).

ρ_f: yarn density, expressed in (g/cm^3).

ε_C: tensile strain at maximum load obtained through calculation.

ε_E: tensile strain at maximum load measured by extensometer.

ΔF: load change value corresponding to the deformation ΔL of the specimen between gauge lengths, expressed in (N).

ΔL: deformation of the specimen between gauge lengths corresponding to the load change ΔF, expressed in (mm).

5 Principle

After the yarn is uniformly impregnated in resin and cured, under the uniform loading of an appropriate mechanical device, it is stretched to break. In accordance with the tensile stress - strain curve, calculate the tensile strength, tensile elastic modulus and tensile strain at maximum load.

The tensile elastic modulus is the ratio of the change in stress to the corresponding change in strain. The stress - strain relation of carbon fiber yarn is nonlinear, so the secant modulus shall be defined. Usually it is defined by two strain points. The linear density and sizing agent content shall be separately measured.

6 Instruments, Equipment and Materials

6.1 Resin

The viscosity of the resin shall be such that the yarn can be thoroughly and uniformly impregnated. The strain at break of the cured resin shall be at least twice that of the fiber. A thermosetting epoxy resin system with a viscosity below 1,000 mPa • s during impregnation is recommended (see Appendix A). The formulations of the resin shall be specified in detail and agreed upon by the manufacturer and the user.

6.2 Resin Impregnation Equipment

6.2.1 The specimen can be prepared by manual method or mechanical method. In the mechanical method, the resin impregnation equipment (see Appendix B) shall include the

6.6 Straight Ruler

A scale or other measuring devices with a measuring range of not less than 500 mm, and with a minimum division value of 1 mm.

7 Specimens

7.1 Number of Specimens

Sufficient specimens shall be prepared to ensure 6 valid data. If the specimen is damaged in the fixture or the reinforcement sheet, or damage caused by the extensometer, it shall be discarded, and re-sampling shall be conducted for the test.

7.2 Specimen Length

The specimen can be tested with or without the reinforcement sheets. The length of the specimen shall be not less than 250 mm; for specimens with the reinforcement sheets, the length of specimen between the reinforcement sheets shall be (150 ± 5) mm.

7.3 Resin Impregnation of Specimen

7.3.1 In order to control the resin content without damaging the fibers, the manual method and mechanical method can be adopted to conduct resin impregnation, and the mechanical method is recommended.

7.3.2 See Appendix A for the manual method for resin impregnation.

7.3.3 The mechanical method for resin impregnation shall use the resin impregnation devices in 6.2 in accordance with the following steps:

a) Place the yarn bobbin on the bobbin fixing device (see 6.2.2);

b) Pour the resin into the resin impregnation tank (see 6.2.3); adjust the temperature and viscosity to the specified values;

c) Let the yarn pass through the resin impregnation tank and roller or steel die (see 6.2.4) and ensure thorough impregnation;

d) Adjust the winding tension, which depends on the experience of each laboratory; the recommended tension is not greater than 1% of the breaking strength of the yarn;

e) Successively wind the resin-impregnated yarn on the frame at a certain interval (see 6.2.5);

f) Put the frame into the temperature-controlled curing furnace (see 6.3);

g) In accordance with the requirements of the resin manufacturer, perform the curing;

h) After the resin is cured, take out the frame from the temperature-controlled curing furnace, and cut a sufficient number of resin-impregnated yarn specimens;

i) In accordance with the stipulations of 7.5, select the specimens.

7.4 Determination of Linear Density and Density of the Same Roll of Yarn

7.4.1 The linear density of yarn shall be determined in accordance with GB/T 7690.1.

7.4.2 The content of yarn sizing agent shall be determined in accordance with GB/T 29761.

7.4.3 The carbon fiber density shall be determined in accordance with GB/T 30019.

7.5 Selection of Specimens

7.5.1 Use a suitable instrument to inspect each specimen. The specimens shall be straight, smooth and uniform, and free from defects, such as: broken yarn, resin shedding and fiber misalignment, etc.

7.5.2 Use a straight ruler (see 6.6) to measure the length of the specimen. After cutting the specified length of specimen and before pasting the reinforcement sheet, use a balance (see 6.5) to weigh the mass of the specimen. By dividing the mass by the length, calculate the linear density of the resin-impregnated yarn.

7.5.3 In accordance with Formula (1), calculate the resin content of the specimen:

$$W = \frac{T_{ti} - T_{tf}}{T_{ti}} \times 100 \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Where,

W---the resin content of the specimen, expressed in (%);

T_{ti}---the linear density of the resin-impregnated yarn specimen, expressed in (tex);

T_{tf}---the linear density of the yarn, expressed in (tex).

The number of specimens in each group shall not be less than 3; calculate the average value of resin content. The resin mass content of the specimen shall be 35% ~ 60%. If the rein content is beyond the acceptable range, then, the resin content of all specimens in the group shall be verified.

7.6 Preparation of Specimens with Reinforcement Sheets

Under the circumstance where reinforcement sheets are used, the length of the fixture shall be at least 30 mm. See Appendix D for the reinforcement sheets and the preparation device of the reinforcement sheets. It is recommended to use cardboard as the reinforcement sheet and use room-temperature cured epoxy adhesive to paste it.

10.3.3 The tensile strain at maximum load calculated through the tensile strength and tensile elastic modulus is calculated in accordance with Formula (6):

$$\varepsilon_C = \frac{\sigma_f}{E_f} \times 0.1 \qquad \cdots\cdots(6)$$

Where,

ε_C---the tensile strain at maximum load obtained through calculation, expressed in (%);

σ_f---the tensile strength, expressed in (MPa);

E_f---the tensile elastic modulus, expressed in (GPa) (see 10.2).

10.3.4 Take the arithmetic mean of the tensile strain at maximum load of all specimens as the reported value; if required by the product specification or the test entrusting party, calculate the standard deviation and coefficient of variation.

11 Test Report

The test report includes the following contents:

a) Serial No. of this document;

b) All necessary details about the yarns tested;

c) Linear density of yarn, and whether the sizing agent is removed;

d) Yarn density, and whether the sizing agent is removed;

e) Whether the tensile strain at maximum load is calculated or directly measured by the extensometer;

f) Number of specimens including the number of discarded;

g) Test speed;

h) Tensile strength, tensile elastic modulus and tensile strain at maximum load shall, if required, be provided as individual values;

i) Calculation method for tensile elastic modulus;

j) Any other details that may affect the test results.

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