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**Test method for pull-through resistance of fasteners of polymer
matrix composite laminates**

聚合物基复合材料层压板紧固件拉脱阻抗试验方法

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1 Scope

This document sets out the principle of the method, the test equipment, the test specimen, the test conditions, the test procedure, the statistics and the test report for the fastener pull-through resistance test on polymer matrix composite laminates.

This document applies to the determination of the pull-through resistance of fasteners in polymer matrix composite laminates.

3 Terms and definitions

3.1 Initial failure force P_i : the peak force reached before the first drop in force of less than 10 % during loading, or the force corresponding to a change of more than 10 % in the slope of the force-displacement curve.

3.2 Failure force P_f : the peak force reached before the first drop in force of more than 10 % during loading.

3.3 Max force P_{max} : the greatest force borne by the specimen during the test.

4 Principle of the method

This method uses the fastener pull-through test fixture shown in Figure 1 to determine the fastener pull-through resistance performance of a composite laminate. A tensile load is applied to the loading clevis connected by the fastener to the laminate, so that the fastener is placed in tension, and the fastener pull-through resistance of the composite laminate is

thereby obtained. The numbered items of Figure 1 are: 1 base; 2 spacer block; 3 channel-shaped support; 4 specimen; 5 loading clevis; 6 pin; 7 loading rod; 8 fastener; DB the diameter of the hole in the channel-shaped support; P the load.

5 Test equipment

5.1 Testing machine and measuring instruments. The testing machine and the measuring instruments shall comply with GB/T 1446.

5.2 Test fixture. The test fixture consists of a base, a spacer block, a channel-shaped support with a hole in it, a loading clevis, a pin and a loading rod; a schematic diagram is given in Figure 1 and the dimensions and tolerances in Annex A. The minimum plate thickness of the base and of the channel-shaped support is 6 mm and is at least twice the thickness of the laminate, and the material shall be a steel material. The diameter DB of the hole in the channel-shaped support is related to the diameter of the fastener, as set out in Table 1.

Table 1 gives, for each fastener diameter, the minimum specimen thickness h for four head types, the minimum specimen width L and the diameter DB of the hole in the channel-shaped support, all in millimetres. For a fastener diameter of 4.0 the minimum thickness is 1.4 for a protruding head fastener, 2.5 for a 100° countersunk tension head fastener, 2.0 for a 100° countersunk shear head fastener and 1.4 for a 100° countersunk tapered-shank shear head fastener and a 130° countersunk fastener, with a minimum width of 68.0 and a support hole diameter of 34.0. For a fastener diameter of 5.0 the corresponding values are 1.5, 3.0, 2.5 and 1.5, with a minimum width of 72.0 and a support hole diameter of 38.0. For 6.0 they are 2.0, 3.8, 3.5 and 2.0, with 84.0 and 50.0. For 8.0 they are 2.8, 4.9, 3.9 and 2.8, with 96.0 and 63.0. For 10.0 they are 3.3, 5.8, 4.9 and 3.3, with 108.0 and 75.0.

6 Test specimen

6.1 Shape and dimensions of the specimen. The specimen is a square composite laminate of uniform thickness; a schematic diagram of the specimen is given in Figure 2. The ratio of the specimen hole diameter D to the thickness h is recommended to be between 1.5 and 3; the recommended minimum specimen thickness and minimum specimen width are given in Table 1. The symbols of Figure 2 are: L the specimen width; D the specimen hole diameter; d_{csk} the countersink depth of the specimen; h the specimen thickness.

6.2 Number of specimens. Each group shall have not fewer than 5 valid specimens.

7 Test conditions

7.1 Test environment. The standard laboratory environmental conditions shall meet the requirements of GB/T 1446.

7.2 Conditioning of the specimen. Before the test, the specimen is kept under the standard laboratory environmental conditions for at least 24 h, or is conditioned under environmental conditions agreed between the two parties.

8 Test procedure

8.1.1 The appearance of the specimen is inspected in accordance with GB/T 1446 and each specimen is numbered.

8.1.2 The specimen is conditioned as laid down in 7.2.

8.1.3 After conditioning, one width and one length of the laminate specimen are measured, and at the same time the thickness at 4 positions around the central hole of the laminate specimen and the diameter of the hole are measured; the thickness is measured to the nearest 0.01 mm and the other dimensions to the nearest 0.02 mm. The ratio k_{CBD} of the diameter of the hole in the channel-shaped support to the diameter of the hole in the specimen is calculated by formula (1), the ratio k_{Dh} of the diameter of the hole in the specimen to the thickness by formula (2), and the ratio k_{csk} of the countersink depth of the specimen to the thickness by formula (3), the results being kept to 3 significant figures. In these formulas DB is the diameter of the hole in the channel-shaped support, in millimetres (mm); D is the diameter of the hole in the specimen, in millimetres (mm); h is the thickness of the specimen, in millimetres (mm); and d_{csk} is the countersink depth of the specimen, in millimetres (mm).

8.2.1 The specimen and the loading clevis are connected by the fastener, and the fastener is tightened with a torque wrench to the specified torque, being the torque used in the actual structure.

8.2.2 The loading clevis is passed through the hole in the channel-shaped support of the test fixture and connected to the loading rod by the pin; the loading rod is then gripped in the head of the testing machine.

8.3.1 The specimen is preloaded, a load of 150 N being applied in order to take up the clearance in the joint. The load is then reduced to 50 N and the alignment of the specimen in the fixture is checked, to make sure that the specimen sits centrally in the test fixture.

8.3.2 A tensile load is applied continuously to the specimen at a loading rate of 1.0 mm/min to 2.0 mm/min; the test is stopped when the load has fallen 30 % from its maximum value, and the load-displacement data are recorded continuously. At the end of the test, the initial failure load, the failure load, the maximum load and the corresponding displacements of the specimen are read from the load-displacement curve and recorded, as shown in Figure 3, and the failure mode is recorded, as given in Table 2; only failure of the laminate at the fastener hole, or failure of the fastener, is a valid failure mode.

Table 2 lists the typical failure modes by code: A, laminate pull-through failure; B, shear

failure of the fastener head; C, fracture failure of the fastener shank; D, stripping of the fastener thread; E, other failure modes.

9 Statistics

For each group of tests, the arithmetic mean, the standard deviation and the coefficient of variation of the initial failure load, the failure load, the maximum load and the corresponding displacements are calculated in accordance with GB/T 1446.

10 Test report

The test report generally includes the following: a) the name of the test item and the number of this document; b) the time and place of the test; c) the source of the specimens and how they were prepared, and the type and specification of the material; d) the number, shape and dimensions, lay-up, appearance quality and quantity of the specimens; e) the test temperature and relative humidity; f) the model, specification and calibration status of the test equipment and instruments; g) the number of the testing machine; h) the loading rate; i) the load-displacement curve of each specimen; j) for each specimen, the ratio k_{CBD} of the diameter of the hole in the channel-shaped support to the diameter of the hole in the specimen, the ratio k_{Dh} of the hole diameter to the thickness, and the ratio k_{csk} of the countersink depth to the thickness; k) the initial failure load, failure load, maximum load and corresponding displacements of each specimen, and the arithmetic mean, standard deviation and coefficient of variation, expressed as a percentage, of each group; l) the failure mode of each specimen.

A Annex A (informative) Dimensions and tolerances of the test fixture

The test fixture consists of a base, a spacer block, a channel-shaped support with a hole in it, a loading clevis, a pin and a loading rod, as shown in Figure A.1. Since the diameter of the hole in the channel-shaped support is related to the diameter of the fastener used in the specimen, the recommended dimensions and tolerances of the test fixture for a specimen fastener of 6 mm diameter are given in Figures A.2 to A.7, covering in turn the base, the spacer block, the channel-shaped support, the loading clevis, the pin and the loading rod.